

RESEARCH DEPARTMENT

PROPAGATION OF BROADCAST TRANSMISSIONS OVER  
THE U.K./JOHANNESBURG CIRCUIT DURING 1956

Report No. K-123

( 1957/8 )

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#### SUMMARY

This report contains the results of an analysis of the signal strength and some other data obtained from the reception log sheets compiled at the Panorama, South Africa, receiving station of the South African Broadcasting Corporation. These deal with reception of B.B.C. transmissions directed towards South Africa during every day of 1956.

The results are presented in the form of block diagrams giving the summarised results, and of circuit graphs giving the detailed results, for each month. In addition certain special effects are examined.

So far as signal strength alone is concerned the service given on the best received frequency in use was found to be never less than good except for a part of the period 0500-0800 GMT in the first two and last three months of the year. The diurnal and seasonal variations in reception are examined, as are the relations of the received signal strength on the various frequencies to the predicted maximum usable and lowest useful frequencies. The periods of less than good service mentioned above occurred mainly when the actual MUF and LUF appeared to differ from those predicted, but there is no evidence that better service could have been given by the use of other frequencies. A small decrease in signal strength occurred shortly after 1800 GMT, particularly during June and July, but a more serious effect at this time was the onset of rapid fading. This resulted in a degradation of the service given between 1830 and 2100 GMT, sometimes to a poor grade, during all months except January, November and December.

#### 1. INTRODUCTION

In this report are given the results of an investigation of the propagation of H.F. broadcast transmissions over the circuit U.K./Southern Africa during every day of the year 1956. The results are given in terms of the signal strength incoming at the S.A.B.C. receiving station at Panorama, near Johannesburg, of the broadcast transmissions from B.B.C. transmitters in the U.K., operating on different frequencies in the H.F. broadcasting bands and directed towards South Africa. The effects of fading are examined during the period 1600-2100 GMT. The aim of the investigation was to determine the general utility of the transmissions in terms of the received signal strength, to discover any significant diurnal or seasonal variations in propagation conditions, to determine the general relation between actual usable frequencies and the predicted MUF and LUF curves for the circuit, and to investigate any special effects which might become apparent, particularly during periods when conditions are difficult.

## 2. METHOD OF ANALYSIS

### 2.1. Data Used

The data used were obtained from the weekly reception logs compiled from observations on the transmissions made at the Panorama receiving station of the S.A.B.C. These give, for each day of the week, graphs of the results obtained during the period of observations, in terms of the five units of the SINPO signal reporting code<sup>1</sup>. Since this report is concerned solely with propagation conditions it was not thought practicable to use the O figure, since this includes the degrading effects of interference and noise, neither of which is directly related to propagation. For the general examination, therefore, only the first graph, giving the incoming signal strength, was used, though, as will be explained in the relevant section, the P figure was also used when it was necessary to examine the effects of fading.

The assessment of signal strength, to produce the S unit of the SINPO code, is subjectively made according to the following definitions:

Excellent signal strength	= 5
Good signal strength	= 4
Fair signal strength	= 3
Poor signal strength	= 2
Barely audible	= 1

The observations were made at intervals of about a quarter of an hour, for the periods when the transmissions were on, during the daily period when the station was open, i.e. generally from 0500 to 2100 GMT. Rhombic aerials were used for reception, so that the signal strengths given would be somewhat better than would be obtained by ordinary broadcast listeners.

### 2.2. Handling of the Data

The signal strength values were read off from the log sheet graphs at hourly intervals, except where frequency changes occurred at times other than on the exact hour, when half-hourly readings were interposed. These hourly or half-hourly readings were set out for every day of each separate month, and a monthly analysis made in terms of the percentage of days when signal strength at the reading time exceeded, or was below, a certain value. Generally readings were available for every day, or nearly every day of the month, but in a very few cases, owing to interference or other reasons, it was possible to make assessments on fewer occasions. In these cases the analysis was still made in terms of the percentage of the total days for which observations were available, except that in no case was a percentage arrived at where the number of readings for the month was ten or less.

Signal strength 3 was considered to be the significant value in indicating the margin between usable and unusable signals from a programme point of view, signals of strength 3 or greater being capable of providing service of programme value provided that the degrading factors are not too great, and signals of strength less than 3 being too weak to do so. For each hour (or half hour) during any month reception was therefore classified as follows:

- i. Signal strength 3 for less than 50% of observation days.
- ii. Signal strength not less than 3 for 50% to 80% of observation days.
- iii. Signal strength not less than 3 for more than 80% of observation days.
- iv. Signal strength not less than 4 for more than 80% of observation days.
- v. Signal strength 5 for more than 80% of observation days.

In order to translate these classifications into terms of the service being given a fairly liberal interpretation of them was made, as follows:

- (1) Poor Service
- (2) Fair Service
- (3) Good Service
- (4) Very Good Service
- (5) Excellent Service

It was necessary to adopt these terms in order to give an idea of the service being given having regard to propagation conditions only, and it is not meant to imply that the overall merit of the signals would be such as to give, in fact, that class of service. This might not be so because of some degrading factor, such as interference, which has not been considered here.

### 2.3. Presentation of Results

The results are presented in the form of block diagrams, Figs. 1 and 14, and of circuit graphs, Figs. 2-13. In the block diagrams the time when no service was attempted or no reportage given is shown by



In the graphs the time when service was attempted and reportage given is shown by the straight horizontal lines: where these are absent either no service was attempted or no reports received. Throughout the year not more than one frequency was used, or reported on, in each broadcasting band. If, in the graphs, the horizontal line appears with no symbol over

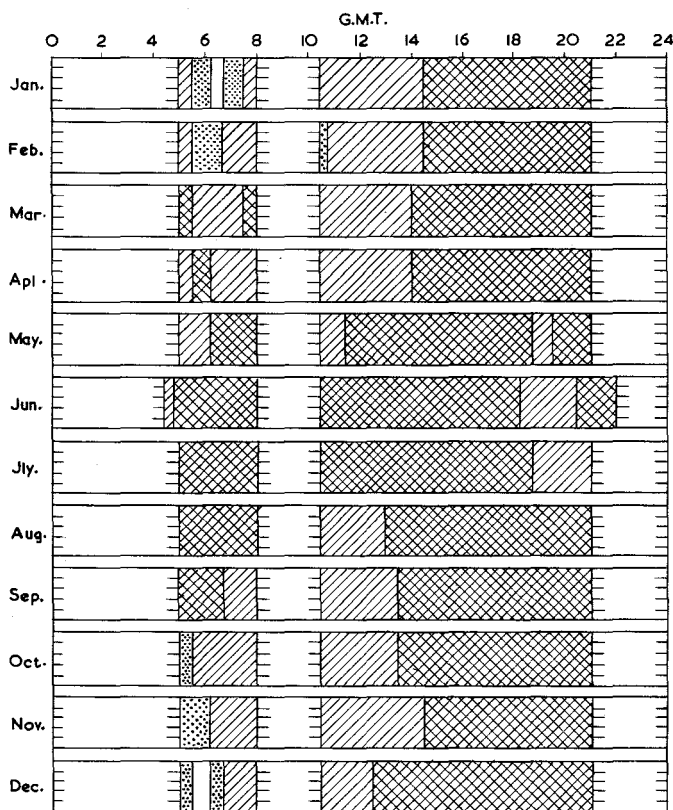
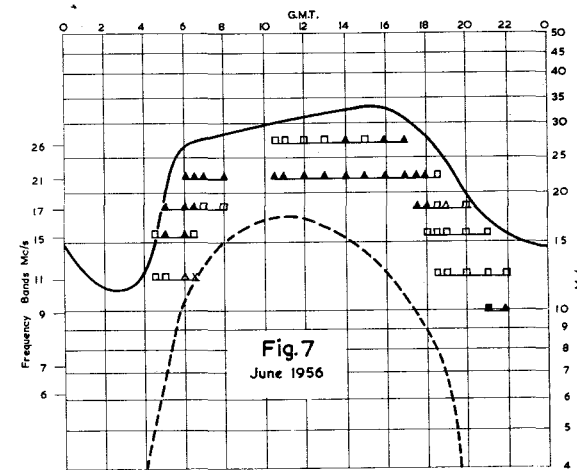
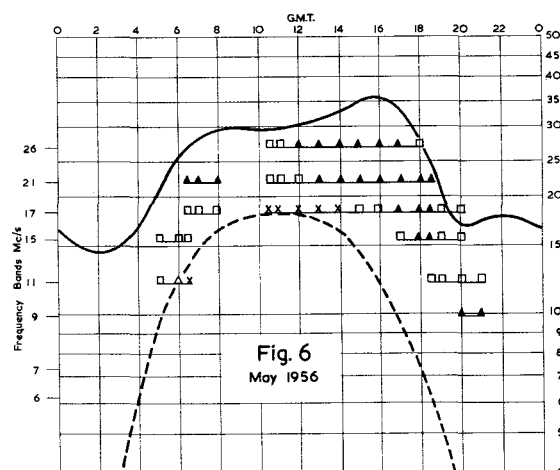
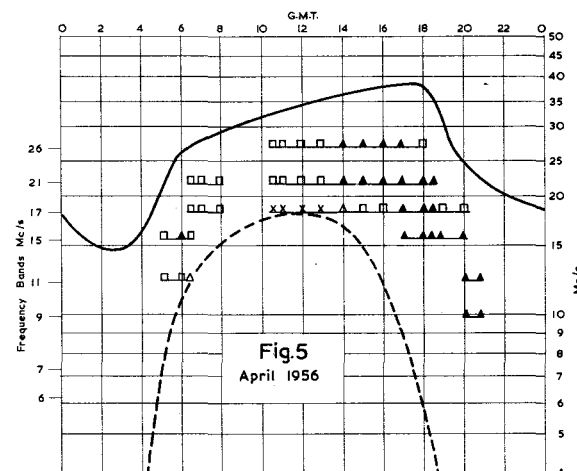
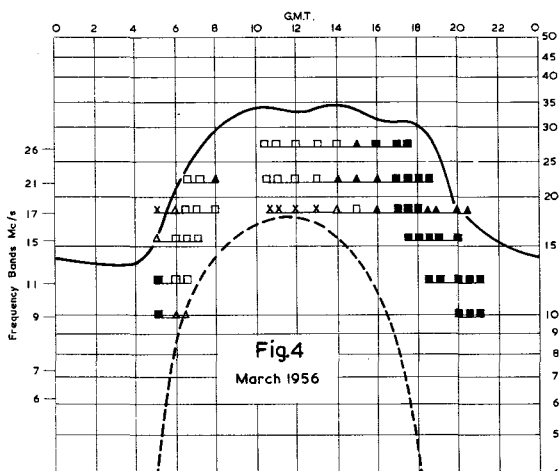
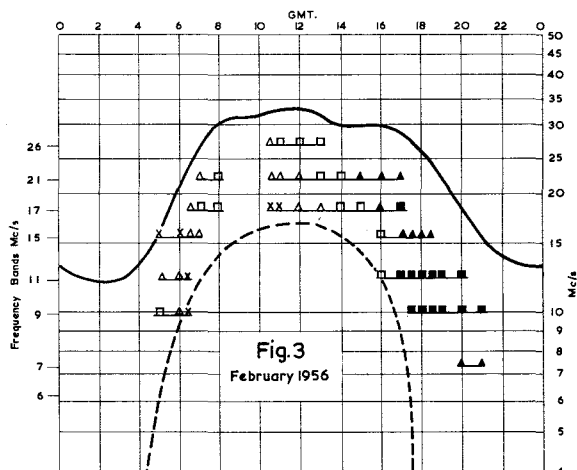
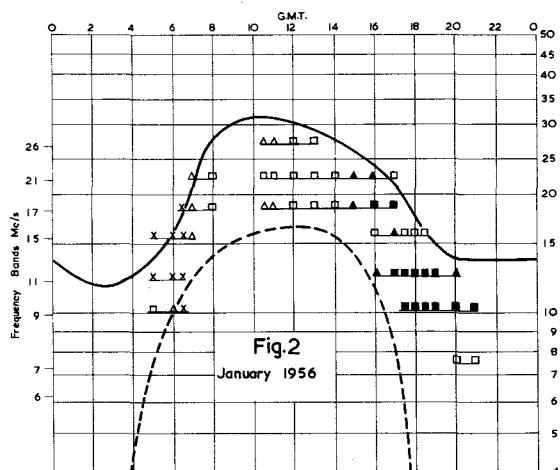


Fig. 1 - Summary of circuit performance 1956 in terms of signal strength on best frequency

- |  |  |
|--|--|
| No service attempted or no reports received  |  |
| Poor service (signal strength 3 for less than 50% of observation days)                     |  |
| Fair service (signal strength not less than 3 for 50% to 80% of observation days)          |  |
| Good service (signal strength not less than 3 for more than 80% of observation days)       |  |
| Very good service (signal strength not less than 4 for more than 80% of observations days) |  |



Figs. 2-7 - Monthly graphs of reception at Johannesburg — January to June

Signal strength 3 for less than 50% of observation days

Signal strength not less than 3 for 50% to 80% of observation days

Signal strength not less than 3 for more than 80% of observation days

Signal strength not less than 4 for more than 80% of observation days

Signal strength 5 for more than 80% of observation days

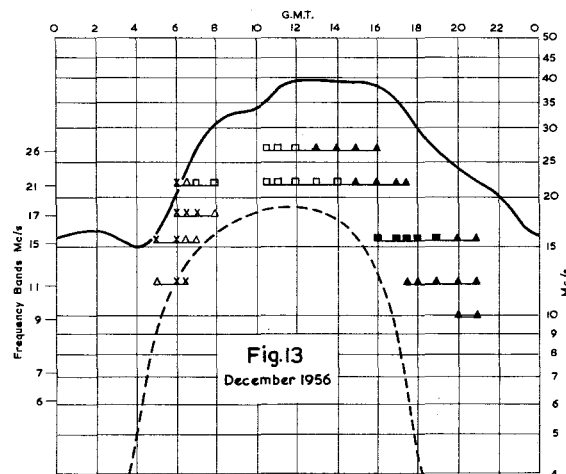
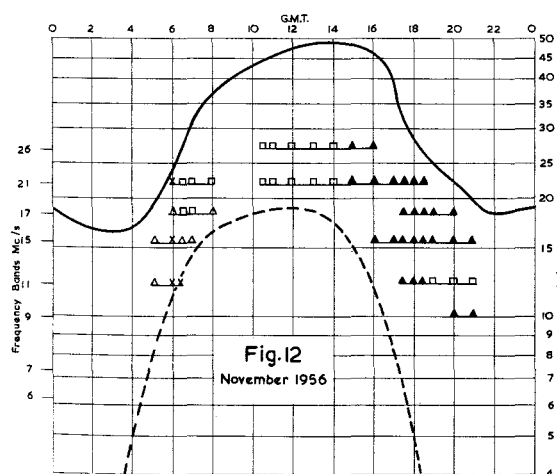
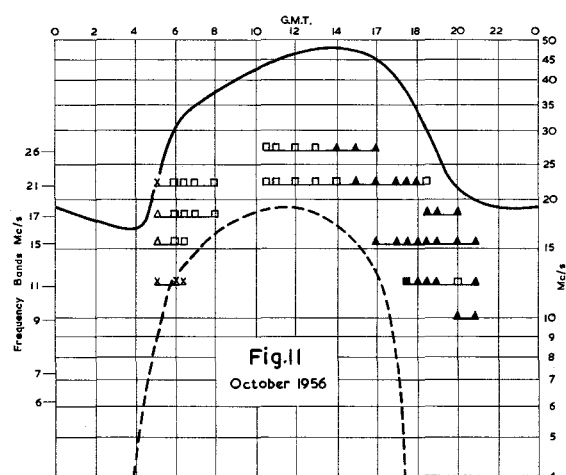
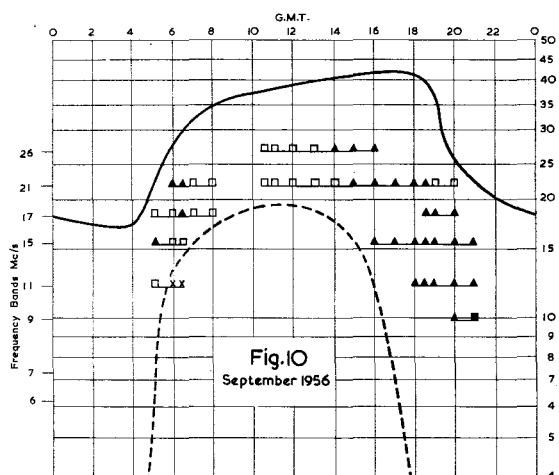
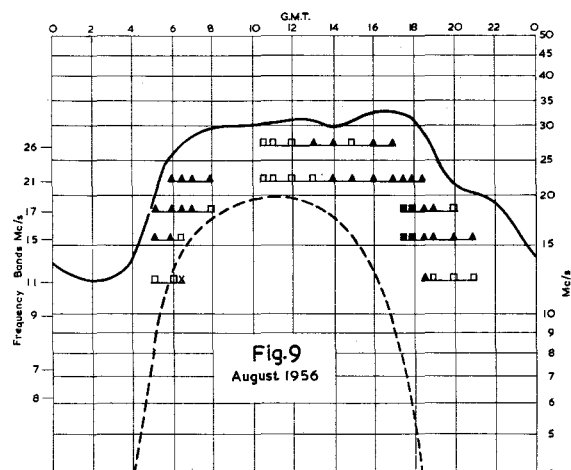
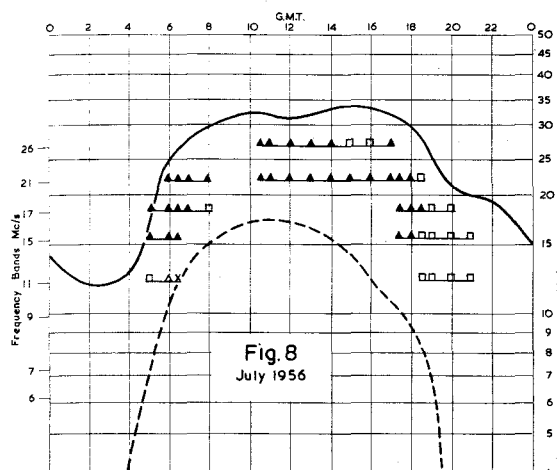
X

Δ

□

▲

■







Figs. 8-13 - Monthly graphs of reception at Johannesburg — July to December

Signal strength 3 for less than 50% of observation days  
 Signal strength not less than 3 for 50% to 80% of observation days  
 Signal strength not less than 3 for more than 80% of observation days  
 Signal strength not less than 4 for more than 80% of observation days  
 Signal strength 5 for more than 80% of observation days

x  
 △  
 □  
 ▲  
 ■



it at one of the reading times it means that there were insufficient readings to analyse. For the rest the symbols have the following meanings and equivalences:

In the Graphs		In the Block Diagrams	
Signal strength 3 for less than 50% of the observation days	x	Poor Service	
Signal strength not less than 3 for 50% to 80% of the observation days	△	Fair Service	
Signal strength not less than 3 for more than 80% of the observation days	□	Good Service	
Signal strength not less than 4 for more than 80% of the observation days	▲	Very Good Service	} 
Signal strength 5 for more than 80% of the observation days	■	Excellent Service	

### 3. DISCUSSION OF RESULTS

#### 3.1. General

The great circle path from the U.K. to Johannesburg is on a bearing of  $156^{\circ}$  from true north, and the distance is approximately 9000 kilometres. The time difference between the circuit terminals is approximately 1 h 52 min, so that either daylight or darkness conditions prevail along the whole path except for very short daily periods.

Fig. 1 gives a monthly summary of the circuit performance during 1956 in terms of the received signal strength on the best received frequency at any hour of day. The number of frequencies reported on at any one time varied from five to two as between different hours of day and different months, and the figure may thus be regarded as showing the best service being given throughout the year, so far as signal strength is concerned. Only during January and December were there any periods when the best service was poor, though during January, February, October, November and December there were periods when it was no better than fair. Apart from one short exception all these poor and fair periods occurred during the morning period, i.e. around and after sunrise along the path, when ionospheric conditions are changing rapidly and both MUF and LUF are sharply increasing. The period 0500-0800 GMT is, in fact, seen to be the most difficult period during which service was attempted, though there was a distinct seasonal variation such that service at this time improved to good in March and April, and to even better than this from May to September. It then became increasingly less than good from October towards December. The reasons for this are examined in Section 4.1.

During the period 1000-2100 GMT the best service, so far as signal strength is concerned, was never less than good during any month. There was, however, a distinct seasonal variation present, in that during the first four months the strongest

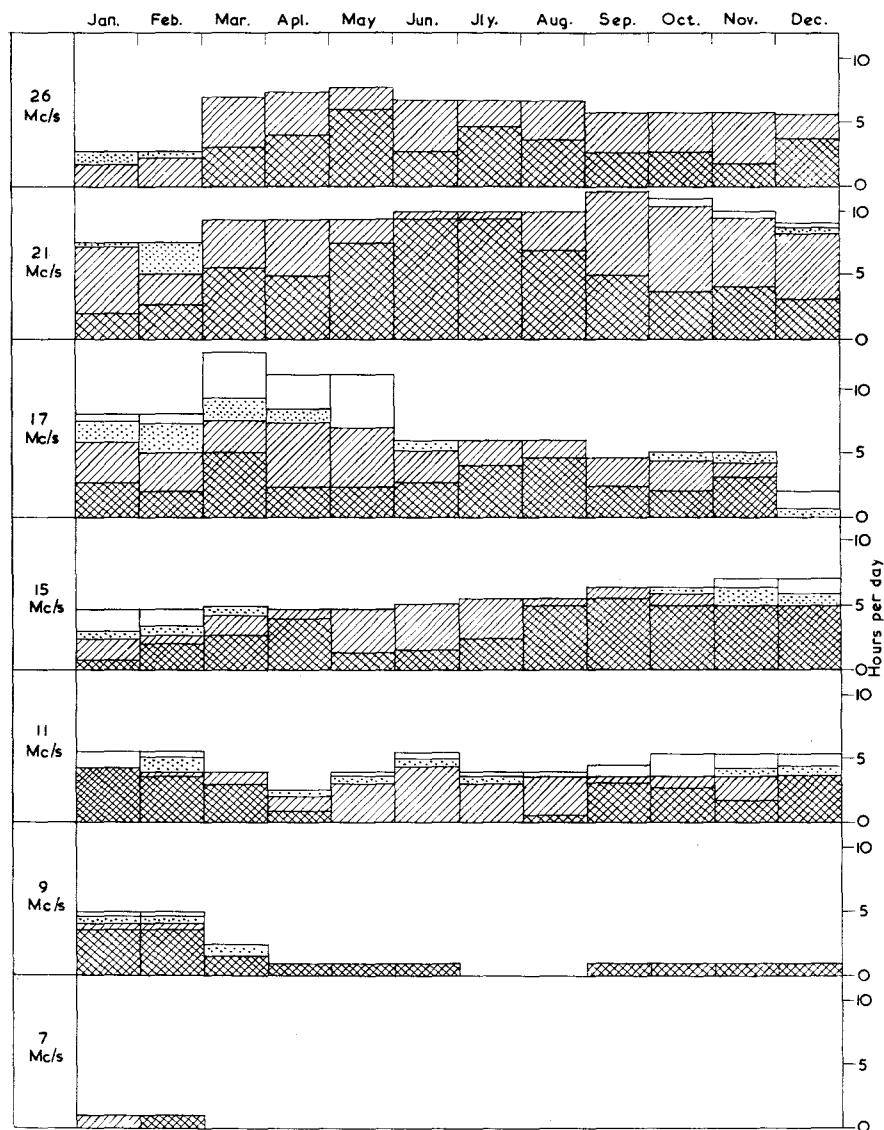


Fig. 14 - Summary of frequency usage and performance 1956

Poor service (signal strength 3 for less than 50% of observation days) □  
 Fair service (signal strength not less than 3 for 50% to 80% of observation days) ▤  
 Good service (signal strength not less than 3 for more than 80% of observation days) ▨  
 Very good service (signal strength not less than 4 for more than 80% of observation days) ▩

signals were received from about 1400 GMT to the end of the period. In May this improved signal strength occurred earlier, and in June and July it occurred from 1000 GMT, with a decreased strength towards the end of the period. From August to the end of the year the highest signal strength again occurred towards the latter part of the period. The reasons for these variations are examined in Section 3.2.

Although the signal strength during the period 1000-2100 GMT was such as never to give less than good service, it will be shown in Section 4.2. that from

1830 GMT onwards there was generally considerable, and sometimes serious, degradation of the service due to the effects of fading.

### 3.2. Predicted MUF and LUF

Figs. 2-13 give the details of frequency usage and performance for each month of the year, together with curves of the predicted monthly median MUF for the circuit as obtained from the D.S.I.R. world U.T. contour charts of predicted MUF using the two-control point method of application, and curves of monthly median LUF obtained from the C.R.P.L. absorption and atmospheric noise data.

The frequencies chosen for operating the circuit were, in general, above the predicted MUF or below the predicted LUF for a very small proportion of the time during any month. A few comments on points of interest in frequency performance in relation to the MUF and LUF curves follow.

*January and February. Figs. 2 and 3.* In January the improvement in the performance of 15, 17 and 21 Mc/s with time in the morning period is obviously controlled by the increasing MUF, and the deterioration in that of 9 Mc/s by the increasing LUF. The reason for the poor performance of 11 Mc/s is not so clear and is examined in Section 4.1. In the evening period 21 Mc/s remained good for a half-hour after predicted fadeout time. In February the same remarks apply, with less force, to the performance of 15, 17 and 21 Mc/s in the morning period, and also to 9 Mc/s. The poor performance of 17 Mc/s just before noon is due to the LUF being high at the time: indeed all frequencies down to 11 Mc/s exhibit a tendency to improve as the LUF falls.

*March to May. Figs. 4-6.* The chief feature is the increasingly poor performance of 17 Mc/s around noon due to the very high LUF at this time and this appears to have been, in fact, somewhat higher than predicted. This frequency was withdrawn at this time of day in June. In March 17 Mc/s remained good for at least half an hour after predicted fadeout time.

*June to September. Figs. 7-10.* Good performance on all frequencies except for the deterioration for half an hour of 11 Mc/s in the morning period with the rise in LUF. The frequencies used were practically always below the predicted MUF.

*October to December. Figs. 8-11.* During the morning period there was an increasing tendency, through these three months, for weak signals to occur, in the case of 11 Mc/s due to the increasing LUF, but in the case of the higher frequencies due to a less obvious reason, since they were all below the predicted MUF. This is examined in Section 4.1. During the rest of the day the performance was good or better on all frequencies, with an increasing signal strength from 1400 GMT onwards. All usage was between predicted MUF and LUF, except for a very short period on 11 Mc/s.

### 3.3. Summary of Frequency Usage and Performance

In Fig. 14 is given, in the form of block diagrams, a summary of frequency usage and performance throughout the year. The values indicated were obtained from

Figs. 2-13, and represent the hours per day, during each month, when received signal strength fell within the categories indicated by the Key, and the total value in each month is the hours per day that each frequency was in use, or was reported on. Generally speaking, because of the effect of the increasing sunspot activity, more use was made of the higher and less of the lower frequencies as the year went on, and this led to the continuance of predominantly good signal strength.

26 Mc/s. Except in January and February this high frequency never gave less than good service throughout the year. During those two months there was a short period of less good service from 1030 GMT, which may have been due to the MUF being lower than predicted at this time. Signal strength tended to increase after 1200 GMT.

21 Mc/s. This frequency never gave less than good service from March to September, and had its best performance in June and July, when it gave better than good service for all but a small portion of the time it was in service. In January, February, October, November and December there were short periods of less than good service at the beginning of the morning period, due to the MUF not being high enough. It is not possible to account for the longer periods of such service in February around noon, for this was not apparent during the other months.

17 Mc/s. Though the service given by this frequency was mainly good or better there were increasing periods of less than good service from January towards May, due mainly to the frequency being too near the LUF around noon. It was withdrawn from service at this time of day in June. Towards the end of the year the less than good periods of service are due to poor conditions during the morning period.

15 Mc/s. This frequency never gave less than good service from April to September. During all the other months the less than good service was due to poor conditions during the morning period.

11 Mc/s. There was a short period of less than good service on this frequency during most months, due to the sharp rise in LUF during the morning period. Service during the major part of the time the frequency was in use was, however, good or better.

9 Mc/s. During the first three months this frequency was employed during the morning session when there was a short period of less than good service due to the rapid rise in LUF. In the evening period during these three months, and during the other months when it was employed *only* in the evening period, its performance was always better than good.

7 Mc/s. This frequency was only employed during the first two months in the evening period, when its performance was good.

On the whole, as can be seen from Figs. 1 and 14, the best circuit performance occurred from March to September, with peak performance in June and July. This was due to the increasingly good performance towards midsummer of 26 and 21 Mc/s. The inferior circuit performance in the first two and last three months of the year

was due to the difficulties, during those months, of giving good service during the morning period, on all frequencies.

#### 4. SPECIAL EFFECTS

##### 4.1. Service During Period 0500-0800 GMT

As has already been mentioned and illustrated in Fig. 1 the provision of good service during the above period did not present a special problem during the months March to September, but during the other months of the year service was less than good for parts of this period even on the best received frequency. Special attention was therefore given to this point.

An inspection of the contour charts shows that during the period the transmission path traverses a region immediately on the daylight side of the sunrise line, i.e. a region where there is a steep gradient of ionisation rising towards the east. Both the MUF and LUF are rising rapidly, and the MUF contour lines lie close together. The MUF at this time is generally controlled by conditions at the northern end of the path, and in the northern hemisphere winter months the gradient at this end is steepest, and furthermore the MUF tends to be lower than during the summer months. If, however, the winter MUF were somewhat lower than predicted, and the LUF somewhat higher, then the poor conditions on all frequencies would be explained.

In Fig. 15 the predicted MUF and LUF conditions are illustrated for the months of January, February, November and December, and, in the light of the observed conditions on the various frequencies, the probable actual MUF and LUF are also shown. It is seen that if the actual MUF and LUF had the probable values shown, the former being generally lower and the latter higher than the predicted values during these months, then there is practically no usable band between the two in January and December, and only a small one in February and November, on which communication can be maintained. Inspection of the 0600 U.T. charts for these months, and comparison of the contours with the sunrise line, seems to indicate that the contours are too far towards the west, i.e. that the rise in MUF is shown to begin too early, and that at 0600 GMT it might well have, in fact, the probable values shown in Fig. 15. Also there is ample evidence, by the performance of other frequencies around the midday period, that the predicted LUF has a tendency, at certain times of day, to be somewhat too low.

It is concluded that the periods of less than good service during 0500-0800 GMT during the winter months were due to the fact that the MUF and LUF were so close together that there was no frequency on which good service could have been given.

##### 4.2. Equatorial Sunset Effect

It has been reported by Osborne<sup>2</sup> that at Singapore around sunset, particularly at the equinoxes, the F<sub>2</sub> layer frequently disintegrates into clouds of ionisation, and he suggested that, as a result, normal ionospheric reflection through tropical regions would be unlikely during the period 1900-2000 LMT at the equinoxes. Since the transmission path U.K./Johannesburg passes through the equatorial regions, with its southern control point in the low latitude of approximately 8° south, a deterioration

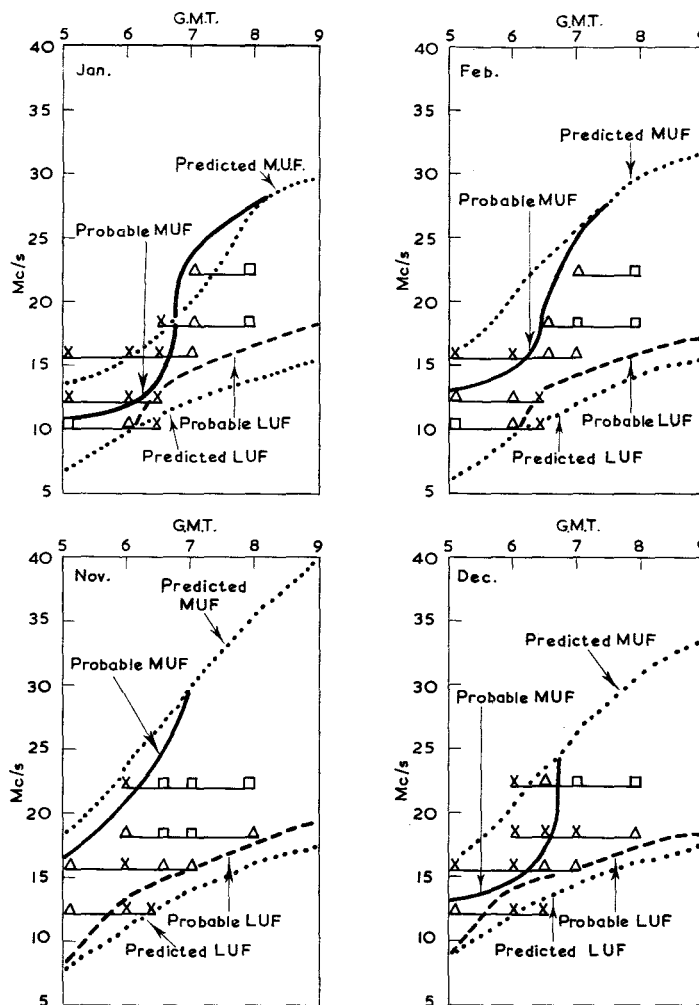


Fig. 15 - MUF and LUF conditions, predicted and those which probably occurred, during the period 0500-0800 GMT

Signal strength 3 for less than 50% of observation days	X
Signal strength not less than 3 for 50% to 80% of observation days	Δ
Signal strength not less than 3 for more than 80% of observation days	□
Signal strength not less than 4 for more than 80% of observation days	▲
Signal strength 5 for more than 80% of observation days	■

in signal strength due to this cause might occur at this time, i.e. 1800-1900 GMT. A previous investigation of reception at Johannesburg<sup>3</sup> did indicate that good reception was not obtained at this time during equinoctial and summer months, and there have also been many reports from there of deep fading at this time.

An inspection of Fig. 1 and of Figs. 2-13 indicates that from April to September there is some deterioration in signal strength at a time between 1800 and 2100 GMT, this being most pronounced and covering most frequencies in June and July. However, the deterioration after 1800 GMT is seen not to be serious, and seldom results in a less than good signal strength on any frequency.

Nevertheless, the grade of service being given after 1800 GMT was seen to undergo a deterioration, and the reason for this was shown in the log sheets by notes as to the incidence of fading, and by variations in the graph of the fourth unit of the SINPO code, giving the values of the P figure for "propagation disturbance". The definitions of this figure and the interpretations placed on them in the log sheets were as follows:

Propagation disturbance nil	= 5 = condition never present
Propagation disturbance slight	= 4 = normal slight fading
Propagation disturbance moderate	= 3 = medium rapid fading
Propagation disturbance severe	= 2 = deep rapid fading
Propagation disturbance extreme	= 1 = condition seldom present

The log sheets show also that, with no interference present, a P figure of 4 does not further degrade the signal (since it is the normal short-wave reception condition), a P figure of 3 degrades it by one grade i.e. for example from good to fair, and a P figure of 2 degrades it by two grades i.e. for example from good to poor.

In order to express these fading effects in equal terms with those used in this report for defining service in terms of signal strength over a period of days, the following logical assumptions were made.

Service as defined by signal strength	P figure not greater than 3 for 20% of days service becomes	P figure not greater than 2 for 20% of days service becomes	P figure not greater than 2 for 50% of days service becomes
Very good	Good	Fair	Poor
Good	Fair	Poor	-
Fair	Poor	-	-
Poor	-	-	-

Thus it will be seen that "good" service which, by our definition, would imply signal strength 4 for from 80% to 100% of days, must be degraded to 3 i.e. by one grade, if fading were no better than 3 i.e. medium rapid, on 20% of days, and similarly for the greater degrees of degradation.

During most of the daily service period the fading was not especially significant, so attention was given only to the period 1600-2100 GMT. For this period the P figure values were read off from the log sheets at hourly intervals, and a monthly analysis made in the above terms, the results of which are given in Fig. 16.

From this it is seen that fading of intensity sufficient to degrade the signal set in on all the frequencies in use at between 1800 and 1900 GMT. It occurred during all months except January, was most prevalent during March, July, August and September, and least so during November and December, in addition to January. It usually became significant at 1830 GMT and remained so until the end of the observation period i.e. at 2100 GMT, though there was a pronounced tendency for it to be less prevalent towards the end of the period. Though it was present on all the frequencies in use it was somewhat less prevalent on the lower frequencies than on the higher ones.

It has been pointed out that all the frequencies were, in most cases, well below the predicted MUF and above the predicted LUF for these times of day, and the time of fading onset i.e. 1830 GMT has no special significance as regards the relations of the frequencies concerned to the MUF and LUF. Furthermore, since it affected all frequencies at the same time the fading would appear to have been due to some special condition in the F<sub>2</sub> layer which occurred shortly after sunset towards the southern end of the circuit. The probability therefore is that it was due to the effect reported by Osborne, though it continued for a longer period after sunset than would have been expected.

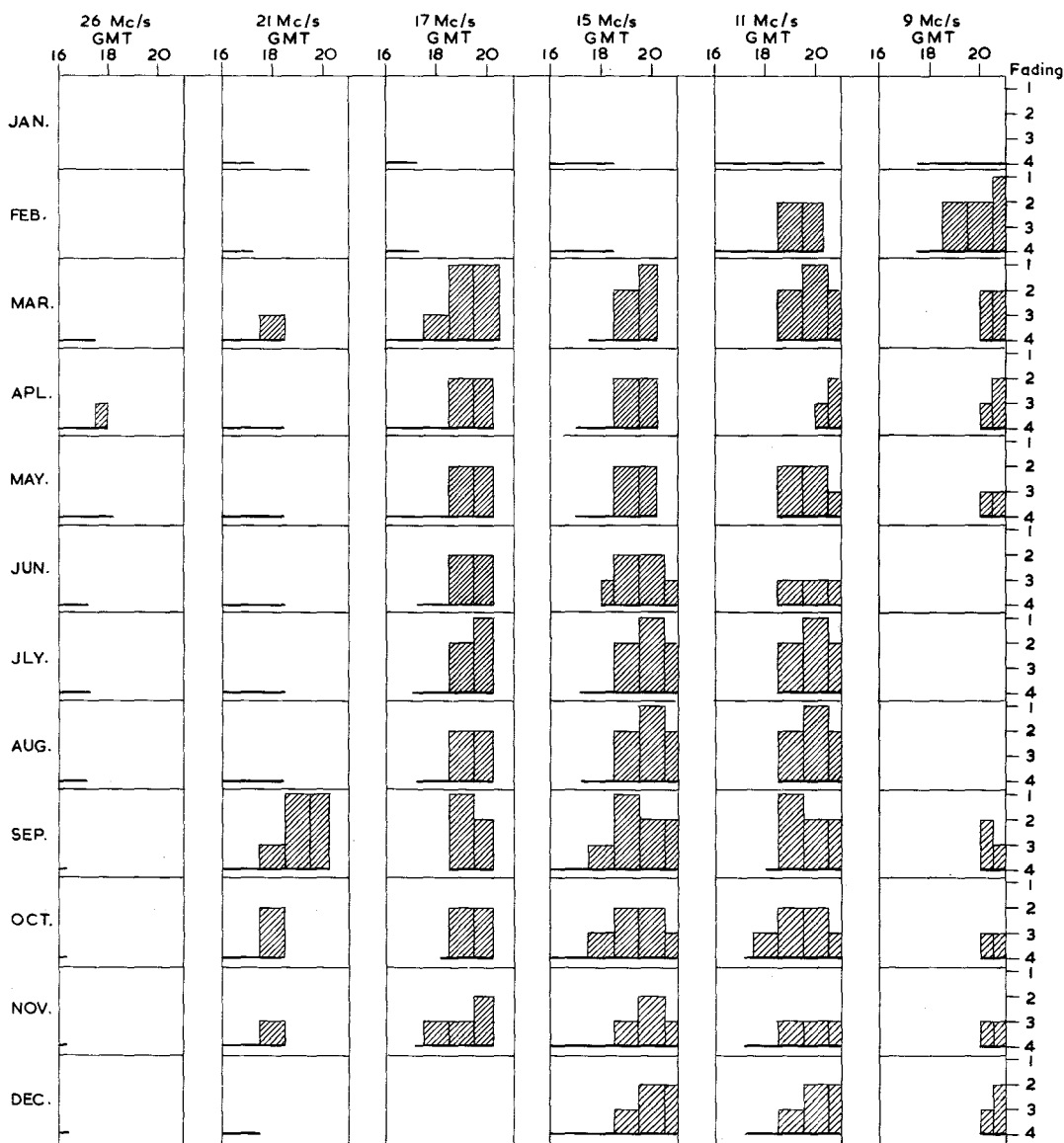


Fig. 16 - Incidence of propagation disturbance (fading) during the period 1600-2100 GMT

- Fading
- 4 = "P" figure 4 for more than 80% of days
  - 3 = "P" figure not greater than 3 for 20% of observation days
  - 2 = "P" figure not greater than 2 for 20% of observation days
  - 1 = "P" figure not greater than 2 for 50% of observation days



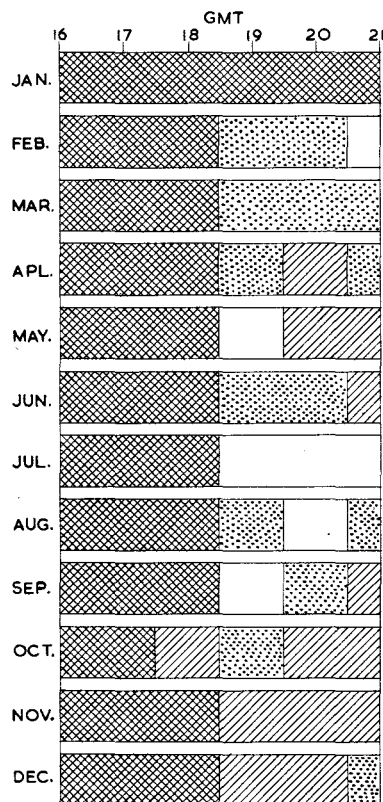


Fig. 17 - Circuit performance from 1600-2100 GMT in terms of signal strength in best frequency, corrected for the effects of fading

Poor service (signal strength  $\bar{3}$  for less than 50% of observation days)

Fair service (signal strength not less than  $\bar{3}$  for 50% to 80% of observation days)

Good service (signal strength not less than  $\bar{3}$  for more than 80% of observation days)

Very good service (signal strength not less than  $\bar{4}$  for more than 80% of observation days)

In order to assess the effect of this fading in degrading the service given, the monthly signal strength gradings for the period 1600-2100 GMT were corrected for the degrading effects of the fading values shown in Fig. 16, according to the degrading terms given earlier in this section. The results are given in Fig. 17, which gives the circuit performance in terms of signal strength on the best frequency, corrected for the fading effects, and which may be compared with Fig. 1. It is seen that, except during the months of January, November and December there was considerable, and sometimes serious, degradation of the service given on the best received frequency from 1800 GMT towards 2100 GMT. It appears that the degradation was worst in July, and serious also in February, May, August and September. During March, April, June and October the degradation was usually to fair service, though sometimes only to good service. This fading, therefore, prevalent on all frequencies, results in less than good service being given from 1830-2100 GMT for a considerable part of the evening during all except the three mid-winter months.

#### 4.3. Distribution of Signal Strength with Frequency

The signal strength indications given in Figs. 2-13 are not sufficiently comprehensive to obtain an exact idea of the distribution of signal strength with frequency over the whole range of frequencies below the MUF, and for the whole 24 hours. Nevertheless, since this is a matter of considerable interest, an estimate of this distribution can be made from the data given in the figures, and examples are given in Fig. 16 for the months March, June, September and December. From these it can be seen that this distribution is complicated, but the following generalisations can be made:

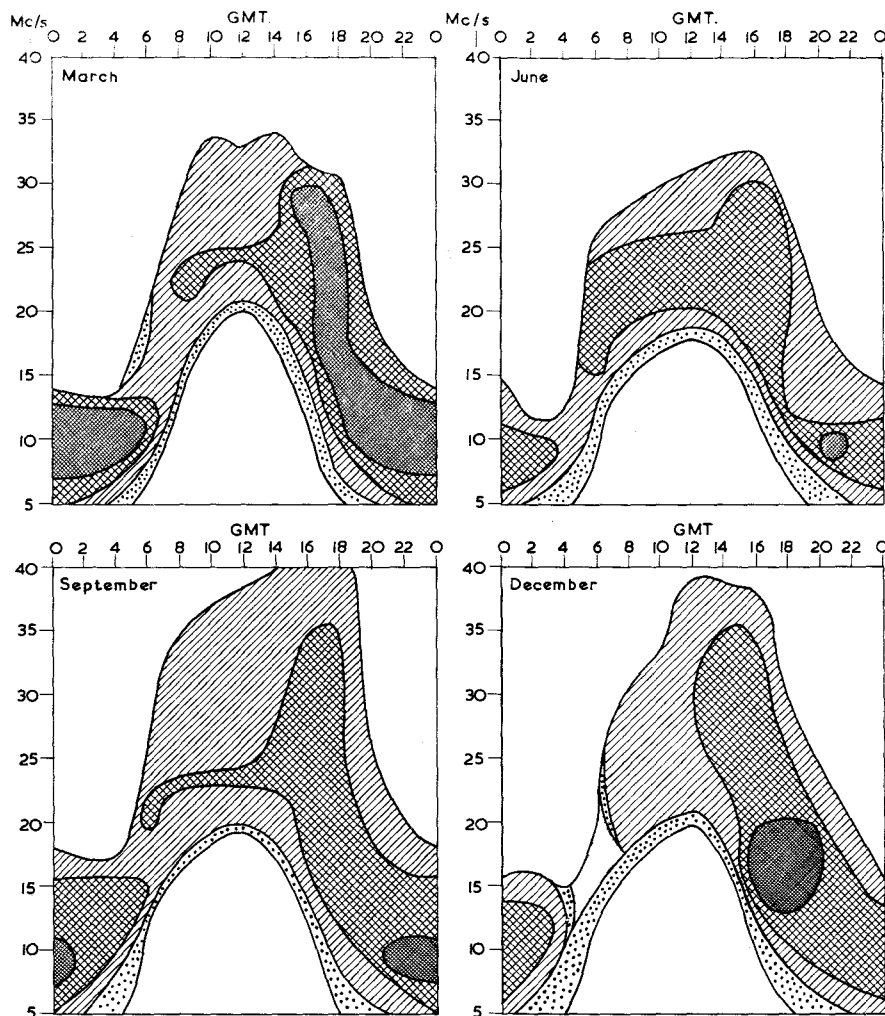


Fig. 18 - Possible distribution of signal strength with frequency

Signal strength 3 for less than 50% of observation days  
 Signal strength not less than 3 for 50% to 80% of observation days  
 Signal strength not less than 3 for more than 80% of observation days  
 Signal strength not less than 4 for more than 80% of observation days  
 Signal strength 5 for more than 80% of observation days



- i. The area of low signal strength on the lower frequencies centred around noon is, of course, due to ionospheric absorption.
- ii. During the period from sunrise to about 1400 GMT the highest signal strength is not immediately below the MUF but is, generally speaking, restricted to a relatively narrow frequency band well below the MUF. The reason may be that it is only within this band that both high and low order modes of propagation are possible: on the higher frequencies the higher order modes penetrate the  $F_2$  layer whilst on the lower frequencies the lower order modes fail to penetrate the E layer at some point on the path.

- iii. The highest signal strengths occur, and extend over the greatest frequency range, during the period after about 1400 GMT (subject to the limitation, particularly in June, of a decrease after 1800 GMT, already mentioned). The reason for this may be that, whilst the higher order modes would still behave as in (ii) above, more energy would be available from lower order modes and over a wider frequency range, because, the E and D layer ionisation now being low, they would be well propagated by the F<sub>2</sub> and would not be subject to heavy absorption.
- iv. At night high signal strengths occur but over a more limited frequency range, for the same reasons as in (iii) but with a much lower MUF.

Whatever may be the full explanation of the reasons for the observed signal strength distribution with frequency over the 24 hours, it is probably intimately bound up with the propagation or non-propagation of the various transmission modes, for the signal strength would vary with the number of these which are present at the receiver simultaneously.

## 5. CONCLUSIONS

The conclusions are as follows:

- a. With the frequency usage as it was during 1956, service, as indicated by signal strength, was never less than good, except for part of the morning period during January, February, October, November and December.
- b. The diurnal variations were such as to produce peak signal strengths towards the latter part of the transmission period, except during the summer months, when high signal strengths occurred earlier, with a small decrease after 1800 GMT. Seasonal variations were such that signal strength during the morning period improved from less than good in January to better than good in June and July and deteriorated again towards December. Over the rest of the day they were such as to cause peak signal strengths to occur earlier in summer than in winter.
- c. For most of the time the operating frequencies appeared to be below the actual MUF and above the actual LUF. The actual LUF, however, appeared to be somewhat higher than that predicted, and service on certain frequencies during the morning period and around noon was less than good because they were below it. During January, February, November and December the MUF during the morning period appeared to be lower than that predicted, with the result that signal strength was less than good on all frequencies.
- d. The effects of fading, presumably due to the equatorial sunset effect described by Osborne, were prevalent on all frequencies from 1830 to 2100 GMT, and resulted in less than good service being given for a considerable part of this period during all months except January, November and December.

- e. The distribution of signal strength with frequency, for frequencies below the MUF, is complicated, apart from the obvious effects of ionospheric absorption on the lower frequencies during daylight. Generally speaking, the strongest signals occur on frequencies well below the MUF, but the frequency range over which they occur varies considerably over the day and night. They appear to occur on those frequencies on which, at any time of day or night, the propagation of several simultaneous transmission modes is possible.

## 6. REFERENCES

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